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ABSTRACT

This publication is designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. Included are teacher guides, student activities, and demonstrations to impart ocean science understanding, specifically, aspects of marine ecology, to high school students. The course objectives include the ability of students to: (1) identify the fundamental source of energy for the marine ecosystem; (2) describe the functions of producers, consumers, and decomposers in the ecosystem; (3) identify typical food webs and food chains; (4) explain relationships between local nutrient depletion and stratification of ocean circulation; and (5) discuss the effects of pollution on the marine ecosystem. This work was prepared under an ESEA Title III contract. The reference page will not reproduce clearly. (Author/EB)

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FORWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-filled waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

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Gary L. Awkerman
Director of Natural Sciences

What are the parts of the marine ecosystem?

Marine Ecology

At the end of this exercise, the student should be able to:

1. IDENTIFY the fundamental source of energy for the marine ecosystem.

2. DESCRIBE the functions of producers, consumers and decomposers in the ecosystem.

3. MATCH a list of organisms to their probable trophic levels.

4. SKETCH a typical food web and a typical food chain.

5. EXPLAIN why the consumption of plants or of herbivores is a more efficient means of obtaining energy than the consumption of high-level consumers.

6. EXPLAIN the relationship between local nutrient depletion and stratification of ocean circulation.

7. LIST three factors which make coastal waters more productive than the open sea.

8. DISCUSS briefly the effect of pollution on the marine ecosystem.

Rationale

The sea is a source of food for millions, a generator of oxygen for the air we breathe, and an absorbant for much of the CO_2 and other wates released by our lungs, cars, and industry. All three of these vital functions depend on a proper functioning of the marine ecosystem. At this point in history, all the major ecosystems of the world are in danger. The sea is the largest of these ecosystems, covering more than two thirds of the globe.

The functions of the sea as a food source, gas exchanger, and waste bin all begin with tiny green plants which drift in the sea as part of the plankton. These photosynthesizing producers take in CO_2 and mineral nutrients and turn them into plant flesh, releasing oxygen as an end product. Both oxygen and CO_2 diffuse back and forth from water to air. Photosynthesis in the sea profoundly affects the makeup of the air we breathe.

The plant flesh built by photosynthesis is consumed by animal consumers who use the plant tissue to make their own flesh. As a general rule, herbivores are eaten by carnivores which are eaten by other carnivores until one carnivore dominates the top of the system. When this carnivore dies, its substance is broken into nutrients which are available for use by another generation of plants. The breakup of top consumers, other dead organisms and their waste products is accomplished by decomposer organisms. These include bacteria and fungi.

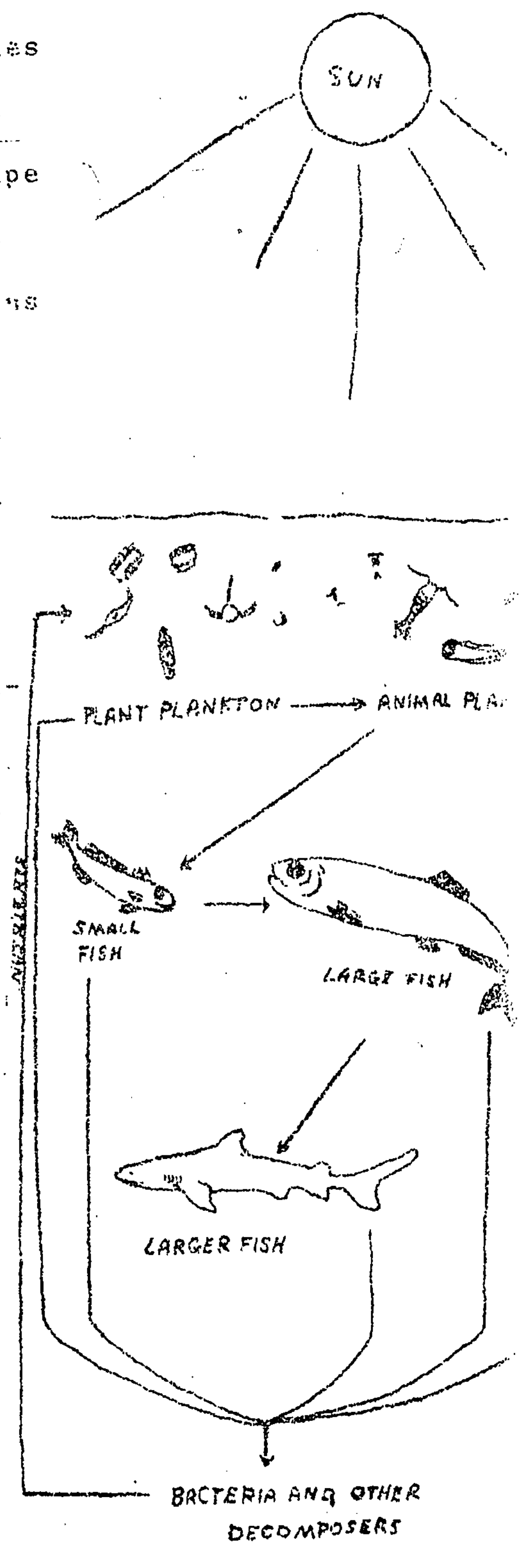
All organisms live in an environment, which can be considered as the total external influences operating on an organism. The ocean environment can influence the spatial and temporal separation of production, consumption and decomposition in the ocean.

The stratification of the sea into several deep layers which flow in different directions can have drastic effects on the availability of nutrients for plant growth. When things die and sink beneath the productive surface layers of the sea, they may hit bottom before the major part of their decomposition is completed. Their nutrients may become dissolved in the waters of some deep current and carried thousands of miles before they reach the surface again and are available for plant growth.

Man can interrupt this ecosystem at many points. If he poisons the producers with industrial wastes, there will be less food for other organisms. If he overfishes for a particular species, the competitors of that species may take over. He may wipe out the species by taking the last of its kind. The whaling industry is a disastrous example of overfishing.

The wastes from man's activities can profoundly affect the marine ecosystem in other ways. If sufficient nutrients are added to the waters, an enormous plant growth can occur. At night when photosynthesis stops, the plants still respire, using up oxygen so rapidly that other organisms in their vicinity may die.

An understanding of the fundamental functioning of the marine ecosystem will help a student to understand what the environmental fuss is all about. The following teacher introduction will help you gain a little background if you have not studied marine ecology before. From this material, you can prepare a short lecture using the transparencies in the teacher demonstrations. The student activities are built around the objectives and the principal points covered in the



teacher introduction and demonstrations.

Teacher Introduction

General

The ocean is a major ecosystem. Like any other ecosystem, it consists of a source of energy to drive producer organisms which are eaten by primary consumers. The primary consumers may be eaten by secondary consumers, the secondaries by tertiary consumers, and so on up the scale to a high-level consumer which utilizes the energy obtained by all the consumers below it. In the food webs involving commercial species, man is often the top consumer. All of these organisms live in an oceanic environment.

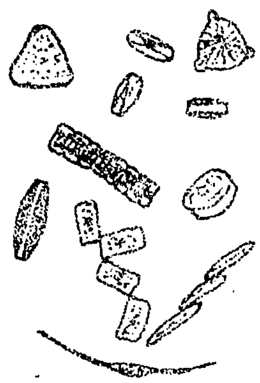
The elaboration of the bodies of the producers and consumers utilizes biologically important elements and compounds. The earth possesses a limited supply of these elements and compounds. If there were no way to return the tied-up substances so they would be available for new construction, the parade of life would have stopped long ago. The break-up of dead bodies to their constituent elements is the role of the decomposer organisms. These perform the essential task of breaking down the complex compounds of dead organisms to simple elements and compounds which may be used in the elaboration of new organisms.

Radiant energy

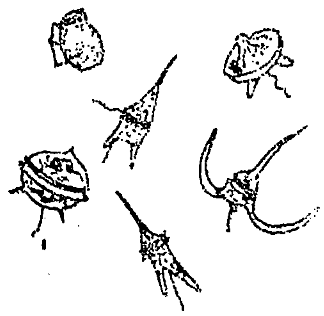
The source of radiant energy for the entire earth is the sun. The incident sunlight illuminates the surface waters and provides energy for photosynthesis. It also warms the ocean to temperatures compatible with biological processes. The warming of the earth by the sun also affects the atmosphere, giving birth to great global wind patterns of the oceans to create great oceanic current systems which circulat the waters of the world ocean around the globe.

Producers and consumers

The principal producers of the open sea are the diatoms and dinoflagellates, microscopic algae which utilize sunlight and mineral nutrients through photosynthesis to sustain themselves and reproduce in the brightly-lit surface waters of the sea. These tiny plants drift about in the water, carried by currents to various regions of the globe.



Diatoms



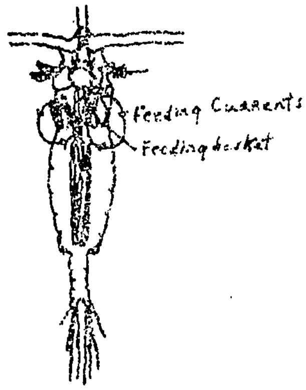
Dinoflagellates

OCEAN PRODUCERS

Tiny, drifting organisms whose transport is at the whim of the currents and not under their own volition are called plankton. Plants in the plankton are called phytoplankton. Drifting animals are called zooplankton.

The primary consumers of the ocean are usually members of the zooplankton. The most important primary consumers in the zooplankton are copepods. Many of these crustaceans feed directly on the phytoplankton. Their specialized mouth-parts set up whirring feeding currents around the anterior end of the animal. The currents sweep diatoms and other debris into a basket formed by bristles on the inside of these appendages. When the appendages are held together, the bristles form a mesh which can trap diatoms. The copepod eats what is trapped in the basket. Diatoms are also used as food by other animals, including various larval forms and some adult animals. These include pteropod mollusks and the larvae of annelids and echinoderms. By far the most important group of herbivores are the crustacea. These include

Copepods



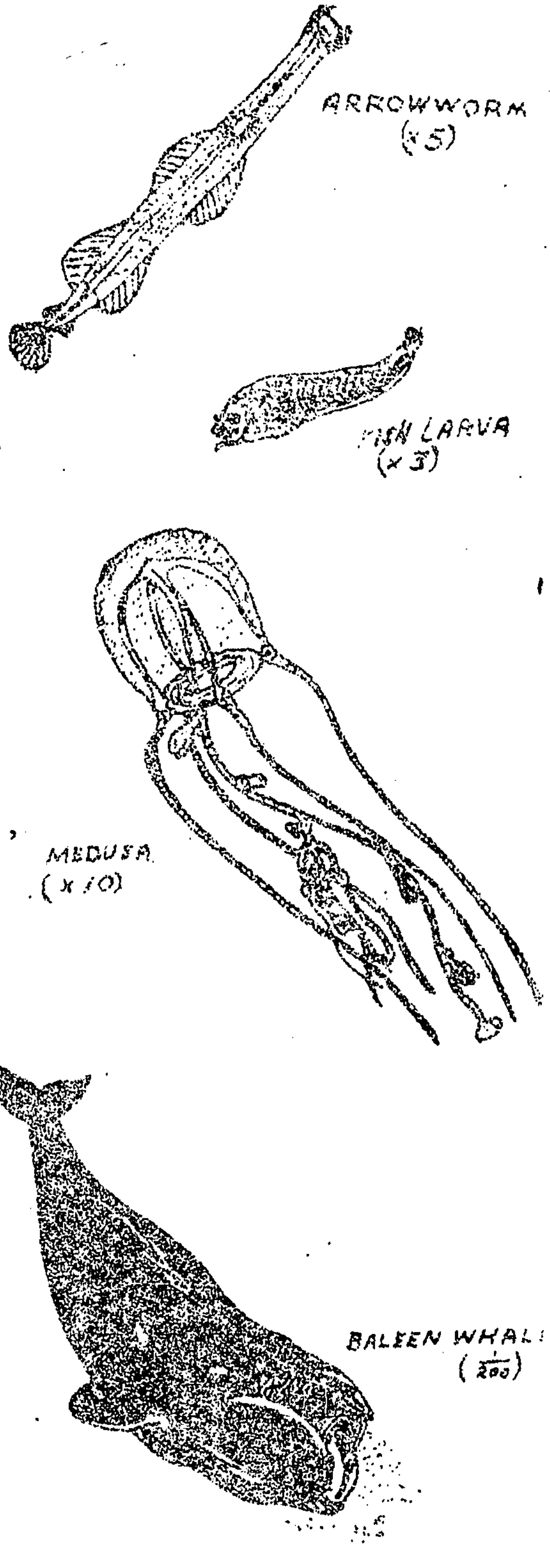
Copepod feeding Currents

PRIMARY CONSUMERS

not only the copepods, but also larvae of large crustacea.. They also include euphausid shrimp. The euphausids superficially resemble the edible shrimp. They are famous as <u>krill</u>, the food of the great whales.

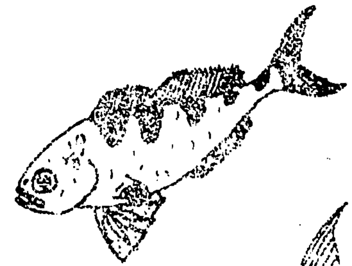
Copepods and other primary consumers are eaten by secondary consumers. These may include many different kinds of animals. Copepods and other zooplankton are important foods of young fish. They are also food for other zooplankters such as arrow worms, carnivorous copepods, ctenophores, medusae, and other small predators. They may also be eaten by relatively large fish such as the adult herring.

Tertiary consumers are the animals which eat the secondary consumers. They may be of various sizes. A ctenophore ingesting a carnivorous copepod which has eaten a herbivorous copepod acts as a tertiary consumer. A predacious fish eating herring which have consumed herbivorous copepods is a tertiary consumer.

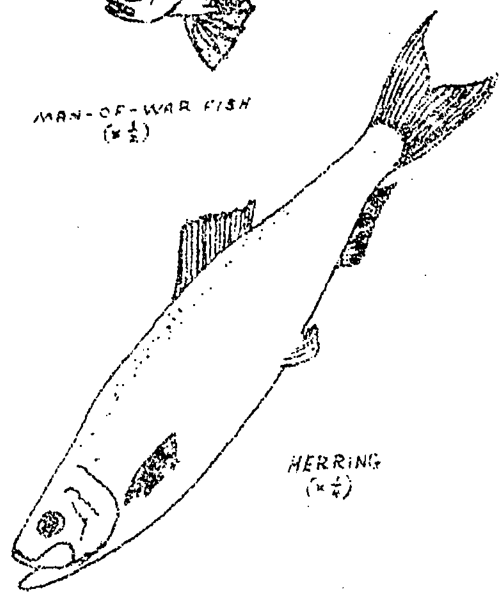


SECONDARY CONSUMERS

There are even higher predators. The herring-eating fish would be a tertiary consumer. It could in turn be eaten by a squid or a larger carnivorous fish, which would be fourth in line. If a man ate the squid or the larger carnivorous fish, he would be fifth in line.



MAN-OF-WAR FISH ($\times \frac{1}{2}$)

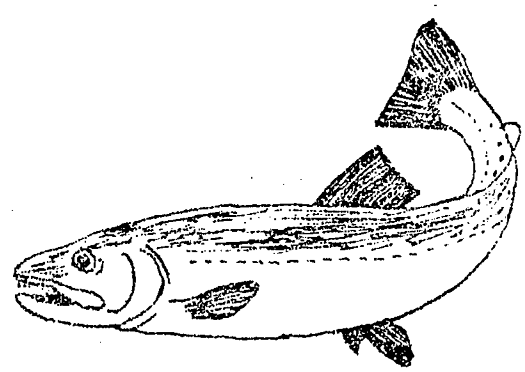


HERRING ($\times \frac{1}{4}$)

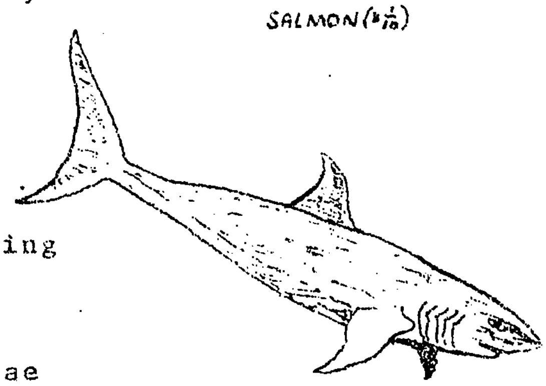
TERTIARY CONSUMERS

Trophic levels

The producers trap energy directly and make their own food. They are called autotrophs. The primary consumers devour autotrophs for their food. They are unable to produce their own. For this reason, they are called heterotrophs. The primary, secondary, and tertiary consumers occupy different levels of heterotrophy. Therefore, we speak of producers and various consumers and decomposers as occupying different trophic levels. It may be further noted that an animal's trophic level is not fixed. For instance, a herring may consume herbivorous copepods, but it may also be consuming carnivorous copepods, arrowworms, and other plankton at the same time. It is operating on several different trophic levels simultaneously. The same goes for medusae and ctenophores. They may trap herbivorous



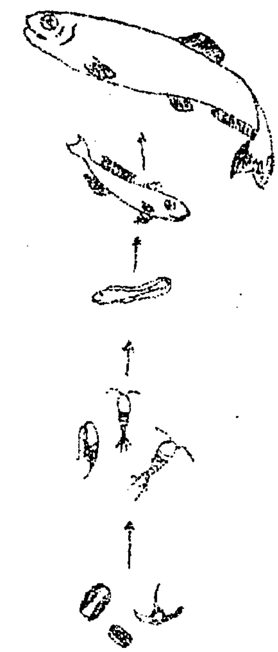
SALMON ($\times \frac{1}{10}$)



MAKO SHARK (× [illegible])

HIGHER CONSUMERS

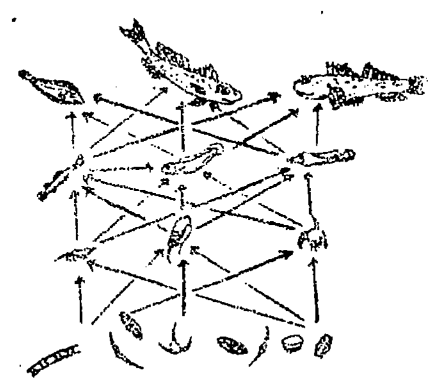
copepods, carnivorous copepods, arrowworms, annelids, smaller medusae and ctenophores, and small fish all in the same day. Rarely will one encounter a series of organisms feeding on only one trophic level at a time.



a. A FOOD CHAIN

Food chains and food webs

A straight-line succession of consumption of prey of only one trophic level at a time from the low trophic levels (plants) to higher trophic levels would result in a food chain. The food chain is still a useful concept, but a simple chain seldom exists in the real world. In reality, the mixture of various kinds of prey and predators of a particular species involves all manner of crossing of trophic levels. The resulting arrangement is more like a food web. A consumer is always higher in trophic level than its prey, but the various prey organisms will differ in trophic level. Examples of a hypothetical food chain and food web are shown in figure 2.



b. A FOOD WEB

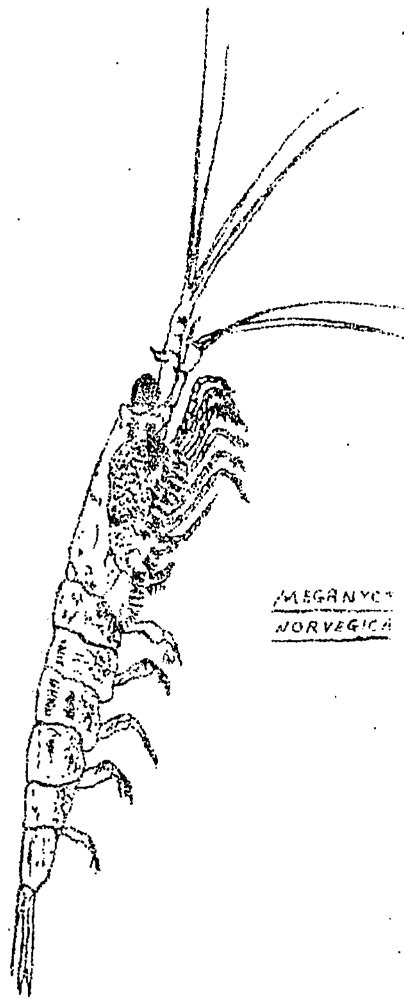
FIGURE 2. FOOD CHAINS AND FOOD WEBS.

Efficiency

The transfer of food energy through a food web is ineffecient. At each trophic level, an organism gains energy either by trapping sunlight (producers) or eating something (consumers). This energy is partly used in building new body substance which will pass on to the animal eating the organism in question. But the animal must also use much of the energy to grow, to maintain its basic metabolism, chase food, run from potential predators, maintain a certain water level, and a host of other activities. These expenditures of energy detract from the amount of energy available to be passed to the next trophic level. At the next trophic level, the same type of expenditure must be made, leaving even less of the original producer's energy to be passed to higher levels. Many units of producers are required to produce one unit of top concumer. For this reason, less top consumer flesh exists over a period of time than producer or lower consumer flesh. When a man eats a high-level consumer, he eats very expensive food. If the high-level consumer happens to be a fish such as mackerel, it has probably fed on rather large fish. Those large fish probably ate smaller fish which ate zooplankton which ate diatoms. The energy represented by a pound of the top consumer's flesh is enormous.

The consumption of lower-level consumers is much more efficient. One highly efficient means of securing protein is to eat whale meat. The meat of a baleen whale is highly nutritious and palatable when properly prepared. The great baleen whales are the terminus of one of the shortest food webs in nature. They eat euphausid shrimp, members of the zooplankton. The euphausids subsist principally on a diatom diet. The strict diet of euphausids makes whales highly efficient gatherers of trapped producer sunlight. The whales represent a great potential store of food of low energy cost for the world's millions if they are managed properly. This is the basic reason why present whale hunting must stop to allow the almost annihilated stocks to rebuild.

The only way we know at present to shorten ocean food chains is to consume



THYSANOESSA RASCHII (x2)

EUPHAUSID SHRIMPS ('KRILL') - THE FOOD OF WHALES. (AFTER HARDY, 1965) the plankton directly. This is not now feasible because of technical difficulties.

Decomposers

Producers incorporate mineral nutrients in the construction of their bodies. The consumers use these nutrients when they eat plant bodies. The nutrients are passed through the web until they are incorporated in the bodies of the highest consumers. Unless man intervenes, nothing eats the top consumers. When they die, they take the nutrients with them. Many consumers and producers do not get eaten. They also die with nutrients locked in their flesh. If there were no means of releasing these nutrients, all the free biologically important elements and compounds in the sea would be locked in dead bodies. New producers would have no nutrients available for growth. The ecosystem would cease to function.

Fortunately, organisms decay. Soon after death, they are attacked by fungi and bacteria which begin breaking them into small fragments. Large organisms may be attacked by scavengers which tear them into small pieces and consume part or all of the body. In this case, organisms such as a blue crab feeding on dead fish may be regarded as part of the decomposer community. The scavengers will eventually die and be attacked by fungi and bacteria as well.

The initial result of decomposition is the breakdown of large organisms into fine particles which are suspended in the water. The bodies of small organisms such as dead zooplankters or diatoms also contribute to the particulate matter. Not only bodies are involved. A large part of what an organism eats is passed out as solid and liquid waste. The solid waste products of metabolism account for a considerable portion of the particulate matter suspended in seawater. The name for this fine matter is detritus. Detritus may serve as a direct food source for many animals, including zooplankton.

Detrital particles also serve as a substrate for further bacterial action. The bacteria convert the detritus to soluble organic matter. The dissolved organic matter includes the liquid wastes of animal and plant metabolism, but it is predominantly formed of stable compounds resulting from plant and animal decay.

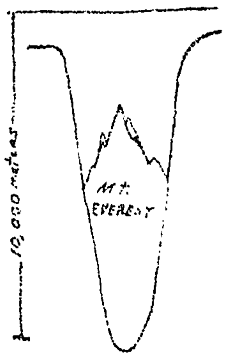
Dissolved organic matter serves as a source of food for bacteria, fungi, and protozoa in the sea. The metabolism of these dissolved organics, especially by bacteria, finally frees the nutrients for use by consumers. The final process of converting decaying matter to free nutrients is called mineralization.

The utilization of dissolved organics by bacteria may take place in direct solution, but its absorption to the surface of detrital particles is a great aid to utilization. Much of the utilization occurs on the surface of sediments on the ocean bottom, where the dissolved organics become adsorbed onto the surfaces of clay particles and other constituents of the sediments.

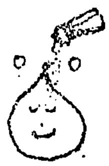
The ocean environment

Most of the processes discussed above probably occur in all regions of the sea at the same time. However, some occur predominantly in special regions of the sea. This semi-compartmentalization is due to certain physical, chemical, and biological aspects of the ocean environment.

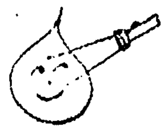
1. First of all, the sea is deep. It extends from the surface to over 10,000 meters. If a large animal dies at the surface, it may sink for a long time before it finally hits bottom and is completely decomposed. This means that its nutrients may be released far from the surface.



2. The sea is composed of water. Water is a universal solvent. This is why the ocean contains so much salt and is able to contain the enormous quantities of dissolved organics that it does.



3. Water is not completely transparent. After light enters the sea, it is absorbed by the water, scattered by detritus and other particles, and further absorbed by the bodies of the organisms in it. Within a few hundred meters all detectable traces of light are gone. Even shallower than this, the light falls



to too low a level to support a photosynthetic rate that will overcome a plant's losses in energy to its own metabolism. This is why all producers in the sea are limited to the narrow upper layers. All life in the ocean subsists on the products of surface photosynthesis.

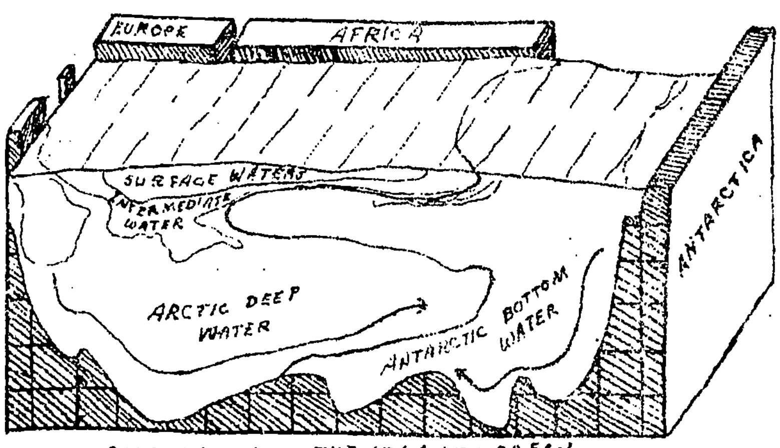
4. There is motion in the ocean. The great ocean currents thoroughly mix the waters horizontally among the great ocean basins over a great length of time. This mixing makes the basic composition of the ocean uniform throughout the world.

Despite the universal mixing of ocean waters, nutrient shortages may occur in the surface layers of the ocean over wide areas. The reason for this is that the oceans are stratified. They exist in several layers from top to bottom. Beneath the warm surface waters are cold, dense waters spreading out over the world ocean from the arctic seas as Arctic Intermediate Water. Beneath the arctic water is even colder, denser water spreading out from the Antarctic. The Antarctic

Bottom Water and other cold masses make up the water of the bottom of the world ocean.

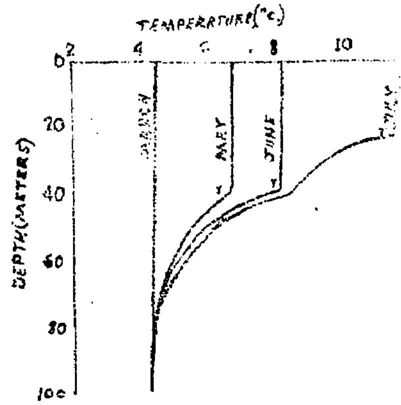
There is little vertical mixture of the oceanic water strata. This is especially true in temperate and tropical areas during the warmer months of the year. As the sun warms the waters in early spring, the depth of warming increases and the warm waters float on the colder waters below. At the bottom of the warm zone, the temperature drops abruptly over a short distance. This boundary layer is called the thermocline.

The waters above the thermocline are essentially a homogeneous mass whose circulation is separate from the underlying layers. Diatoms grow in the warm



CIRCULATION IN THE ATLANTIC OCEAN
(AFTER DIETRICH, 1957)

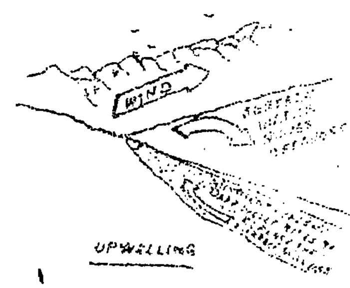
surface layers in immense profusion, lowering the quantity of available nutrients. Much decomposition is accomplished after organisms sink below the thermocline. This removes nutrients from the surface waters. As a result, the surface waters can become depleted of nutrients during productive months of the year. The onset of autumn gales and the lower temperatures of approaching winter cool and agitate the waters, eliminating the thermocline. This joins the surface water to the deeper circulation and replenishes the nutrients in preparation for the next year's growth at the surface.



DEVELOPMENT OF A SUMMER THERMOCLINE, "T" = DEPTH OF THERMOCLINE. (From Weyl, 1970).

The relatively permanent stratification of the ocean into surface, Arctic Intermediate, and bottom waters also causes a lag in nutrient replenishment. If an organism sinks in mid-ocean and is mostly broken down there, its nutrients may be dissolved in bottom water or Arctic Intermediate Water depending on depth and remain in that layer until the layer surfaces in high latitudes.

The phenomenon of deep-water nutrient release explains the extremely high productivity in areas of upwelling. Nutrient rich bottom water rises to the surface along ridges in far northern waters. The nutrients contained in this water are released for use by surface producers when it surfaces. In a similar fashion, Arctic waters slide up the surface of descending Antarctic Waters in far southern seas, bringing nutrients to surface producers there.



Areas of upwelling exist in places of strong winds which blow along a coastline. The winds push surface water offshore. Deeper waters rise to bring nutrients to the producers at the surface. One example of a great upwelling area is off the West Coast of South America. This is the center of a giant fishery for anchovies and other fish feeding on the abundant life in these cold, nutrient-rich waters.

The physical and chemical factors we have just discussed constitute the abiotic environment of marine organisms and detritus. The patterns we have seen are constantly modified by other organisms. The actions and other effects of these organisms constitute the biotic environment.

5. The biotic environment effects the ecosystem in a number of ways. The most obvious way is in providing producers, consumers, and decomposers. The biotic environment of a particle of detritus includes organisms which eat it or break it down. These may consist of bacteria, fungi, and other detritus eaters.

One of the principal side branches to the pattern of surface production and bottom decomposition are the mid-water and bottom organisms. The entire community below the depths of effective photosynthesis subsists on a detrital rain from above.

In the darkness of deep ocean waters, filter feeders strain out particles of detritus from the water and deposit feeders ingest bottom oozes to extract their adsorbed dissolved organic matter. Filter feeders and deposit feeders are eaten by other organisms which are in turn eaten by others. When the terminal predator dies, the branch ends and decomposition joins with the general course of decomposition in the sea.

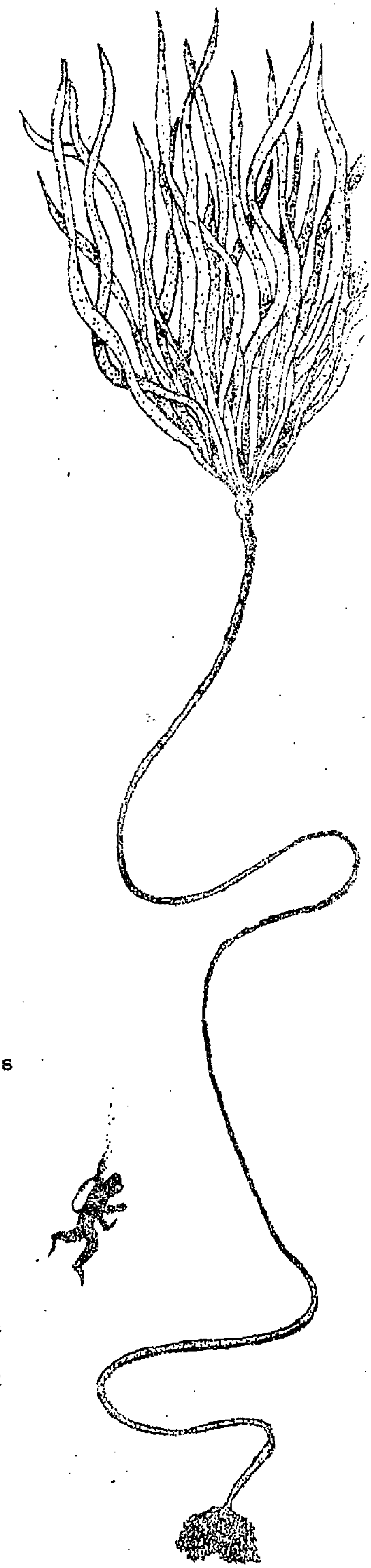
All side branches and all organisms eventually meet the same fate: death, decomposition, and release of nutrients. This great recycling keeps the ecosystem going.

The margins of the sea

In the shallow waters at the margins of the sea, the basic pattern of the ecosystem functions, but the spatial and temporal separation of functions is not so marked. In many coastal waters, sunlight extends to the bottom and the whole cycle from production to mineralization can take place in a limited area.

Coastal waters are highly productive compared to the open ocean. Coastal waters include the waters out to the edge of the continental shelf. They also include estuaries, which are dealt with in greater detail in their own section.

Along the coasts of most nations, the sunlight reaching the bottom enables great masses of attached vegetation to grow. These include the kelp forests of the Western United States and great meadows



KELP

of undersea grasses in many parts of the world. These stands of rooted vegetation form both food and refuge for thousands of species wandering through them or using them as homes.

When an animal dies in shallow water, much of its decomposition will take place in waters which may be only a few meters deeper than the layer in which it died. If it comes to rest on the bottom, it is readily recirculated to the same water mass in which it lived.

In addition to nutrients locally recycled, the coastal waters receive massive additions of nutrients from fresh waters running off the land.

The combination of surface to bottom productivity, nutrient-rich terrestrial runoff, and the fact that the whole process from production to mineralization occurs in a relatively homogeneous water mass all combine to push the productivity of coastal waters far above that of the open sea.

Pollution of the ocean environment

If any material becomes part of the environment, it becomes part of the ecosystem. If the substance is harmful, it may hurt the ecosystem as a whole.

If a certain insecticide were introduced with harmful effects on the producers, all consumers would have less food. The same goes for any number of substances, including volatile petroleum products, mercury, lead, or any of the other substances currently discussed. The substances need not be introduced directly to the sea. If a person dumps something into the Mississippi, it will eventually reach the Gulf of Mexico. If the pollutant is particularly long-lasting, it will eventually circulate through the whole world ocean.

Pollution of the ocean has reached the point of alarming many eminent oceanographers. The sea is the source of much of our oxygen, an absorber of the CO_2 from our lungs and industries, and a source of food for millions. If we pollute to a high enough level, the marine ecosystem will be damaged beyond repair. If the ocean has been that heavily polluted, the land and air will be, too, and the days of life on earth will be numbered. The destruction of our environment is the most pressing issue of our time.

Summary

Sunlight provides the energy to drive the marine ocosystem. The sunlight is trapped by phytoplankton, which are eaten by herbivorous zooplankton. The herbivores are fed on by carnivores which are eaten by higher carnivores. All organisms eventually die if not eaten. They are attacked by scavengers, fungi, and bacteria, and they and their waste products become particulate detritus. The detritus is converted to dissolved organic matter which is finally mineralized by bacteria.

Production and mineralization may be separated in both space and time in the open ocean, but are generally closer together in coastal areas.

Pollution of the marine ecosystem could have serious effects on the affairs of man and other lifeforms. The entire earth ecosystem is presently endangered by the action of our species.

Teacher demonstration 1

1. Give a short lecture on basic ecosystem components based on the teacher introduction ending with the section on decomposers. You may illustrate the lecture by using the following transparencies. The lecture will be continued with the next teacher demonstrations.

2. Display the first transparency, "Life in the Sea" (Oceanography series #0-19, Hubbard Scientific Company). This transparency gives a short hypothetical food chain from producer to large fish across the top. The lower 2/3 of the transparency shows the ocean ecosystem including the sea.

   You may point to the sun as the primary source of energy to drive the ecosystem and to warm the ocean to life-compatible temperatures.

   With your finger or a pointer, trace out the path from phytoplankton (producers) to animal plankton (zooplankton consumers) to a fish (secondary consumer) to the shark (tertiary consumer). Explain to the class that all uneaten matter eventually is consumed by decomposers (scavenging crustacea and bacteria). On the left, point out the ascending arrows through "bacteria". These represented mineralized nutrients going back to "plant plankton."

You may follow the chain to whales here if you desire. Be sure to point out that the fish interposed between the "animal plankton" and the whale are only incidental to the whale's diet. It is really after the animal plankton, and the arrow directly from animal plankton to whales is the most representative route. The fish are useful in pointing out that when fish are engulfed along with a plankton meal, the whale is actually feeding at several trophic levels, depending on the species of fish which get in the way.

3. The circles across the top of the transparency can be used to illustrate a food pyramid and the inefficiency of energy transfer through the trophic levels. There is a very large "plant plankton" circle and smaller successive

circles until "large fish" is represented as a very small circle. Only one large fish is represented. The small circle may be thought of as representing the portion of large fish's flesh which may be built through consumption of the preceding organisms. Actually, one chain stops at "medium fish". A large fish consumes several such chains.

Teacher Demonstration 2

1. Continue your short lecture on marine ecology with this demonstration on the ocean environment. First introduce the concept of the environment as all aspects of the world in which an organism lives. Introduce the terms abiotic environment and biotic environment, with a few samples of aspects of each. The transparency "Components of the Marine Environment" (OSCSP transparency master, Figure 2) will help in this explanation. Abiotic environments include all the physical, chemical, geological, and meteorological aspects of the organism's world. The biotic environment includes food, enemies, sheltering plants, etc.

   Show the transparency "Components of the Marine Environment". The examples listed under biotic and abiotic are only a partial list. Ask the class if they can think of any more to add to each list.

2. Show the transparency "Divisions of the Ocean" (Oceanography: No. 820-1, Instructo Corporation). You used this transparency in the section "Where do we find life in the sea?". Its use at this time will

The Marine Environment

An organism's world

Abiotic - The nonliving environment	Biotic - The living environment
Light	Prey
Waves	Predators
Currents	Decomposers
Pressures	Sheltering plants
Turbulence	Beneficial associations
Salinity	
Winds	
Sediment size	
Substrate	
Shelter	
Nutrients	
Detritus, etc.	
Depth	

Figure 2. Components of the Marine Environment

refresh zonation upon their minds and remind them that the sea is <u>deep</u>. Use the transparency in the following manner:

3. Display the basic transparency with overlays put to the side. Ask the class to name the regions as you point to them. (Continent, continental shelf, slope, plain, and trench.)

4. Place overlay #1 in position on the basic. This will confirm the identifications of regions for those who remembered them and help those who did not. If a large portion of the class could not recall the regions, go over them again briefly. Ask the following questions:

    a. <u>How deep is the trench?</u> (10,000 meters)

    b. <u>Does light go all the way down?</u> (No)

5. Put overlay #2 in position. This will show the extent of the photic zone and give some depth measurements.

6. Put overlay #3 in position to refresh the class on the names of biotic zones. Ask the following questions:

    a. <u>Do organisms live in all depths</u>? (Yes)

b. Where would production occur? (In the lighted surface waters.)

c. Where does most decomposition occur? (On the way to the bottom and on the bottom itself.)

d. What forms the basic food of the communities below the light (photic) zone? (They subsist on a rain of detritus and dead bodies coming down from the photic zone.)

7. Ask the class, "What two basic physical factors of the marine environment can you see in this diagram?" (The sea is deep and light penetrates only a short distance.)

Activity 1 (Life Science or Biology)

1. Take the class to a salt marsh at high tide. Marshes are very characteristic of estuarine shores in the Southeast. Pick a time of high tide so the class may work with the ebbing tide.

2. Divide the class into three groups. The duties of the group should be as follows:

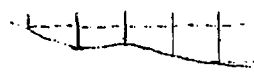
   Group I: Physical characteristics of the salt marsh. They will also lay the transects for stations worked by groups II and III.

   Group II: Producers of the salt marsh.

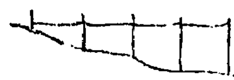
   Group III: Consumers of the salt marsh.

3. Group I. Divide this group into 3 subgroups.

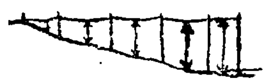
   a. Subgroup A should put a stake in the ground at high tide mark. As the tide recedes, they should put stakes in the ground at 5 or 10 meter intervals until low tide. The tops of all stakes should be at least as high as the bottom of the high tide stake. A string will be stretched along the stakes when the tide is out.

   b. Subgroup A should stretch a string along their stakes from high tide to low tide. The string should be level. A sighting level can be used to level the string.

   c. Two members of the group should measure the distance from the string to the ground at 1-meter intervals from the supratidal to the low water mark. They should plot their measurements on graph paper to develop a profile of the study area. Four stations for sampling should be assigned in the supratidal, high

intertidal, low intertidal, and subtidal regions of the transect line. The stations should be marked on the profile.

d. Subgroup B should measure the temperature and time of exposure of each zone. They should make the following temperature and exposure-time studies:

1. Measure the temperature of the air at a height of 10 cm. above the ground, on the surface, and at a depth of 3 cm. below the surface of the ground. The subsurface temperature may be obtained by gently working the tip of the thermometer into the soil. The 3 centimeter depth is not critical. Most thermometers have a ring a few centimeters above the bulb. Pushing the thermometer into the ground to the level of this ring is sufficient. The essential thing is uniformity in depth of measurement. The same goes for the 10 cm. of the air measurement.

2. If ghost crab or fiddler crab burrows are present, the thermometer should be placed as far down the burrow as possible for a temperature measurement.

3. One set of measurements should be made at supratidal, high intertidal, and low intertidal stations as soon as they are exposed by the falling tide.

4. The time of emergence of each station from the water should be recorded.

e. One member of Subgroup B should put a thermometer on the surface and in the ground to the 3 cm. mark at each station as it emerges from the water.

This team member should read the temperature of both thermometers at each station as soon as it emerges from the water. A member of the subgroup should be stationed with each pair of thermometers for the duration of the activity. They should read the surface and subsurface thermometers each 10 minutes - at closer intervals if the temperature is changing very rapidly, such as on a hot spring day. These measurements do not have to be made on the actual transect line. They may be made off to one side but in parallel with each sampling station.

f. Subgroup C should measure the salinity of the water. They should use a salinity refractometer or whatever other method is available.

Samples should be taken at each station just before the water leaves it. At low tide, salinity samples should be taken as the tide rises again. Sampling should be stopped at low water mark when the water becomes uncomfortably high. Directions for measuring salinity are enclosed with the particular instrument used.

4. Group II will sample the producers of the area. Divide Group II into the following subgroups:

<u>Subgroup A</u>: Producers of the supratidal.

<u>Subgroup B</u>: Producers of high intertidal.

<u>Subgroup C</u>: Producers of the low intertidal (mud flat).

<u>Subgroup D</u>: Producers of the subtidal.

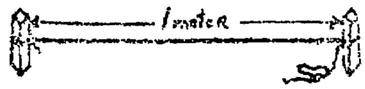
a. Subgroups A-C should each receive the following items of equipment:

3 Trowels
1 meter-quadrat string
10 plastic specimen bags
1 meter stick

Subgroup D should be equipped with:

a plankton net
plastic specimen bags
small jars

A meter-quadrat string is easily made by tying a 5-meter string to a stick. Stretch the string out to one meter. At the one meter mark, tie on another stick. At similar 1-meter intervals, tie on two more sticks. The remaining string should be tied to the initial stick at a distance of one meter from the last stick. The assembly of string and sticks may be placed on the ground as a square (Be sure to get 90° angles!) containing exactly one square meter. Plants and animals may be counted in this square to determine a quantitative estimate of the abundance of various species of plants and animals in the square. The construction and use of the quadrat string is shown in figure 1.



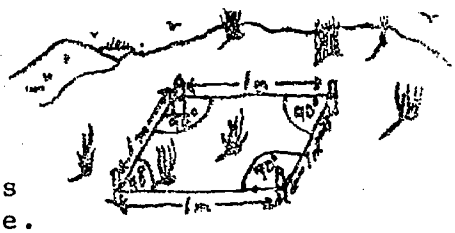


FIGURE 1. CONSTRUCTION AND USE OF A QUADRAT STRING

b. Subgroups A-D should go to their appropriate stations on the transect line. The sampling should be done using the transect string as a mid-line for the square-meter quadrat.

c. Subgroups A-C should set up their quadrat strings to count the plants in one square meter of soil under the string. They should count all plants for a total number of plants in one square meter and also individual numbers for each type of plant they can distinguish.

d. The height of the various species of plants in the quadrat should be measured. A sample of five or ten should be measured for each species if that many are found in the quadrat.

e. The group should collect one or two plants of each kind for identification in the lab. They may be collected with the trowel and put in plastic bags with a little soil.

As much as possible of the root system should be taken. They should note how far beneath the surface the root system begins. If it is buried beneath a few inches of soil, it may have acted as a trap for wind or waterborne particles and helped to build up the marsh or dune in which it is found.

f. When subgroups A-C finish their transects, they may be assigned to count quadrats in the higher levels of the marsh if the vegetation is noticeably different.

g. All stations on the transect should be plotted on the profile drawn up by Group I. Their distance from each other and their varying elevations can be taken from the profile.

h. Subgroup D should take a plankton sample with a fine plankton net in the subtidal zone. This will serve as a sample of planktonic producers of the marsh and local estuary.

i. If the area of your field trip is known for abundant rooted algae in the subtidal zone, be sure that members of subgroup D examine the dredge samples of Group III.

5. Group III will sample the consumers of the marsh - the animals.

a. Divide Group III into four subgroups as follows:

Subgroup A - animals of the supratidal

Subgroup B - animals of the intertidal

Subgroup C - seineable animals of the subtidal

Subgroup D - dredgeable animals of the subtidal

Directions for use of the seine and the dredge are located in the beach zonation exercise in the section. "Where do we find life in the sea?"

b. Subgroup A should be given a shovel and plastic bags. They should roam to either side of the transect line, digging animals out of holes, checking through masses of seaweed and under other objects on the beach, and otherwise looking for animals in the supratidal. Supratidal species may be somewhat scarce. The collectors should wander fairly far to either side of the transect line.

c. Subgroup B should be equipped with a shovel, sieve, and plastic bags. They should work the high intertidal and low intertidal quadrats set up by Group II.

d. Members of subgroup B should dig up portions of the quadrat and put them in the sieve. The sieve should be taken to the water and jostled about to remove the mud from the animals.

   Specimens obtained by sieving should be put in strong plastic bags with enough water to cover the animals by a centimeter or so. The bag should be closed by twisting from the top. As the twisted portion grows longer, the bag should belly out from trapped air. This air will increase the amount of gas exchange to animals in the water.

e. Someone should collect a handful of mud from each quadrat and put it in a bag with enough water to cover it. By the day after the field trip, many small animals should have moved from the mud to the water. DO NOT ADD FORMALIN TO THIS BAG!

f. The sampled area should be measured for width, length, and depth. This will enable quantitation of contained fauna by area and by volume of mud.

g. Subgroup C should seine the subtidal to obtain samples of animals living on the surface of the bottom and swimming in the water. They should seine against the prevailing current. This procedure will keep the seine in a pocket formation which will keep animals in the net.

The group should seine two or three times in a line perpendicular to the transect line.

h. Subgroup D should dredge the bottom of the subtidal to obtain samples of animals lying flat on or buried just under the surface of the bottom. The dredging should also be done against the prevailing current.

6. At the end of the exercise, all plants and animals should be in plastic bags. A profile of the marsh should be complete with the stations plotted on it. Salinity, temperature, and times of immersion should be available for each station.

If any of the equipment is muddy, the mud should be washed off in the water. On return to the school, all equipment should be rinsed in fresh water.

A sample of each kind of organism on the marsh and mud flat should be preserved. 5% formalin is good for invertebrates. Ten percent formalin should be used for fish. Use a scalpel to put 1-2 centimeter slit in the abdomen of any fish over 3-4 cm. in length. The cut will allow the formalin to enter the abdomen to preserve the internal organs.

All large plants should be mounted on herbarium paper. Plant and animal plankton should be preserved in

5% formalin.

The animals which remain alive should be put in the marine aquarium in the classroom as soon as the class returns. Put only a few of each kind in the aquarium, being careful not to overcrowd.

Activity 2 (Life Science or Biology)[1]

1. All prepared material collected in activity 1 should be placed on a table in preparation for the rest of this activity. Do not expect this activity to be absolutely quiet. If the class is to do its work well, there will be a certain amount of conversation and moving around. The conversation and movements should be as quiet as possible. General directions for the exercise are as follows:

    a. Clear all tabletops of unneeded coats, books, pocketbooks, etc.

    b. Microscopes should be pushed well onto the table and not used too near the edge.

    c. Microscopes should always be transported with one hand under the base and the other around the arm. The microscope should be held in a vertical position at all times. The high power of the microscope should be used only on the plankton samples, and then only sparingly.

2. Equip each student with a hand lens.

3. Set out reference books for identification of the organisms. Some handy volumes are listed below. Asterisks (*) designate most essential volumes.

    *Abbott, R. T., 1968. Seashells of North America. Golden Press, New York. A standard guide.

[1]Extensively adapted from Taylor, B., and W. Hon, The Field Approach to Coastal Ecology, Carteret County Regional Marine Science Project, Carteret County Schools, Beufort, North Carolina.

*Dawson, E. Yale.
How to Know the Seaweeds, William C. Brown, Dubuque, Iowa. An excellent, profusely illustrated layman's guide to the algae commonly known as seaweeds.

*Zim H. S., and H. H. Shoemaker, 1955. Fishes, A Guide to Fresh and Saltwater Species. Golden Nature Guides, Golden Press, New York. Usually available at local bookstores. The scientific names of the fishes are listed in the back of the book. A very nice first book of the fishes.

*Zim, H. S., and L. Ingle, 1955. Seashores. Golden Nature Guide, Golden Press, N.Y. A good inexpensive guide for general identification of seashore plants and animals. Scientific names are given in the back of the book.

Breder, C. M., Jr., 1948. Field Book of Marine Fishes of the Atlantic Coast. G. P. Putnam's sons, New York. This is a higher level book with a key to almost all marine fishes found on the Atlantic coast. If a fish is not in the Golden Field Guide, Fishes, it is probably in Breder.

Pratt, H. S., 1948. A Manual of the Common Invertebrate Animals. Blakiston Co., Philadelphia. A more advanced invertebrate book. Very good for students who wish to pursue the identification of any animals not found in Zim and Ingle.

Radford, Ahles, and Bell, 1968. Flora of the Carolinas. A profusely illustrated key to the plants of the Carolinas, including the marsh and beach plants. Almost any wild plant can be identified with this book. It is fairly technical, but perusal of the introductory material in front should enable the more knowledgeable students to do quite well on their identifications.

Teal, J., and Mildred Teal, 1970

Life and Death of the Salt Marsh Ballantine Books, Inc. New York. Probably available at your local bookstore. A beautiful book: a poetic story of marshes - how they arose, how important they are, and their relationship to man. The graceful line drawings throughout the book will help in identification of both plants and animals in the marsh.

4. Divide the class into two groups. They will work with the following organisms:

   Group I - Producers of the salt marsh

   Group II - Consumers of the salt marsh

5. Group I should divide themselves into two groups:

   Subgroup A - Producers of the plankton

   Subgroup B - Osmotic relations and rooted producers

6. The group as a whole should discuss the biblical quotation, "All flesh is grass" before beginning work. Guide the discussion to get the students to deal extensively with the consumption of plants by animals.

7. Subgroup A will study the producers of the plankton obtained from the subtidal zone. Equip them with microscopes, slides coverslips, droppers, paper towels, lens paper, and the plankton samples. They may then study the plankton in the following manner:

   a. Reach into the bottom of the plankton organisms to a clean slide. Put a cover on the slide.

b. Observe the plankton organisms, using the low power lens. Count the diatoms present, and any green dinoflagellates which appear. The members of the groups should answer the following questions:

A. Do you see any diatoms that look like the pictures you have seen of these organisms? _______________

B. How many kinds do you see? _______

C. Do a quick sketch of each type of diatom you see and tell how many you have found.

8. Subgroup B will work with the rooted marsh producers. They should have the following items on hand:

a. osmometer
b. concentrated salt solution
c. distilled water
d. dye (any water-soluble dye)
e. rooted plants obtained from the tidal transect.

9. Various members of subgroup B should carry out the following procedures:

a. Fill the bag of the osmometer with distilled water to which enough dye has been added to produce a reasonably dense color.

b. Fill the cup of the osmometer with the concentrated salt solution.

c. Assemble the osmometer. Mark the water level in the tube.

One member of subgroup B should be assigned the task of watching the osmometer to alert the rest of the group to any changes which occur.

10. Changes should begin to occur in the osmometer within a short time. Other members should begin plant identifications (Step 11). The subgroup should then be able to answer the following questions:

a. Did a color change occur? ________

b. Where, and in what direction?________

c. What have you learned from this exercise about movement of fresh and salt water? ____________________

d. Your body cells contain salt at a concentration of 9 o/oo. What would happen to you if you were lost at sea and drank salt water? (35 parts per thousand) ____________

e. Apply the same principle to plants. They also possess relatively low salt concentrations but live in high-salinity environments. What sort of basic problem is faced by these plants.____________________

____

11. During the time the osmometer is operating, subgroup B should be identifying the rooted producers obtained from the quadrats on the previous day's field trip.

For each quadrat, a list should be made of the species and plants found and the numbers in which they occurred.

12. The number of species and numbers of plants of each species present in each quadrat should be plotted on the beach profile obtained on the field trip the previous day.

13. At this time, it may be desirable to make a larger copy of the profile for class display. One or two members of the class may be given the task of making a profile poster on a large piece of poster board. If desired, small herbarium mounts of the principal species at each station can be pasted to the large profile chart. They may be arranged in natural groupings to represent the plant communities at each station.

14. The dominant factors in the environment of the marsh plants are salinity and time of immersion. The members of the subgroup should examine the diversity of species and sizes of the plants at each station and try to reason why a particular species is found where it is.

An example of the questions they may ask themselves is, "Why are there no algae in the supratidal?" The answer is that they dry out when exposed. Some algae can withstand lengthy periods of emergence. Many more algae can withstand short periods of being left behind by the falling tide, other species can live submerged at all times. This is the reason for looking at the numbers of species of plants at each station. If a significant number of algae are found, the students should examine them to find differences which might signify adaptations to differing periods of dryness.

Intertidal algae may be regarded as plants that are invading the land from the sea. They must adapt to periods of dryness.

Plants with true roots, stems, and leaves, such as cordgrass (Spartina) or burrweed (Borrichia) represent the reverse situation. They are terrestrial plants invading the margins of the sea. The students should look for adaptations to the high salinity and other conditions of the marsh. Life and Death of the Salt Marsh will serve as an excellent reference for these adaptations.

15. Group II will work with the consumers of the salt marsh. Divide into subgroups with the following areas of investigation:

Subgroup A - Animal behavior

Subgroup B - Distribution of marsh consumers.

16. Subgroup A should work with the living animals obtained from the previous day's field trip. Among the animals they probably found are:

Oysters
Mud snails
Marsh periwinkle snails (from the marsh grass)
Fiddler crabs
Mud crabs
Shore crabs
Mussels (small to large black, ribbed bivalves)
Small animals (contained in the mud sample: taken on the field trip)

17. Equip subgroup A with several finger bowls, a little bit of carmine, and hand lenses. Stereomicroscopes will be helpful if they are available.

18. Subgroup A should take the live specimens from their bags and put each kind in a separate finger bowl of seawater. They should observe the animals to answer the following questions:

   a. Which of the animals are most closely related?

   b. What are the reasons for their answers?

19. Oysters and mussels are filter feeders. One of each kind should be opened. The shell half which contains the animal should be placed in a finger bowl half full of clean seawater. Use separate finger bowls for each specimen.

20. The experimenters should sprinkle the exposed oyster and mussel with a bit of carmine powder and observe the animals to answer the following questions:

   a. What happens to the carmine particles?

   b. Why do you think this is

happening? (*Answer:* The animals are eating the particles)

c. Does either animal have a mechanism for sorting out the particles?

d. What sort of feeding relationship probably exists between the oyster and the surrounding seawater, particularly the plankton?

e. Is there any noticeable difference between patterns, rates, or other aspects of particle movement between the oyster and the mussel?

f. Do you notice anything different in the methods by which the oyster and the mussel attach themselves to the substrate?

21. The students should observe a fiddler crab and some other crabs in finger bowls of seawater. They should answer the following questions:

a. How do these crabs differ? In body form? In behavior?

b. Look at the claws of the various crabs. Are they any different? How about the legs?

22. The students should cut up an oyster or mussel and offer bits of it to the crabs. If any shrimp are handy, pieces of these may be offered. The feeding behavior of the animals may be observed, and the students should try to answer the following questions:

a. Does the crab accept the food?

b. Does he grab it fast, or relatively slowly?

c. How does he handle it?

d. Do the crabs seem able to handle extremely fine particles, such as the oyster and mussel handle?

e. How do you think the feeding

habits of crabs and the oyster and mussel differ?

23. The students should observe the mud snails and marsh snails in finger bowls half full of seawater. The students should try to answer the following questions:

    a. What are the differences between the two kinds of snails?

    b. Does either of them come to the surface or crawl out of the water?

    c. Which one?

    Visit the table when they have found the marsh periwinkle snail (Littorina) out of the water. Ask, "What is the most available high structure for Littorina to climb as the tide rises?" (Answer: marsh grass). Ask them, "Where do you think you would find this snail at high tide?" (Answer: clinging near the exposed tops of marsh grass.)

24. One or two students should pour the supernatant water from the field trip mud sample into a dish. They should examine the dish with a hand lens or stereomicroscope (if available) to see how many different kinds of animals can be found in the mud.

25. Subgroup B should mostly occupy themselves with identifying the preserved animals from the transect. They should develop species number and animal number lists (#species/#animals = diversity) just as the producer group did.

26. Subgroup B may also wish to develop a poster-sized chart of the marsh profile just as Group I did.

27. The subgroup should look for adaptations to the different tidal zones of the marsh to answer the following questions:

a. How does the diversity of the marine animal population differ in the different tidal zones?

b. How do the types of animals differ? (For example, one finds no fish in the supratidal. Among the crustacea, few kinds of shrimps will be present at low tide, but several kinds of crabs may be found.)

28. At the end of the exercise, both groups should report their results to the class as a whole. One convenient way of handling their reports is to have one member of each subgroup report for the subgroup.

29. When the reports are finished, the class will construct a chart of the salt marsh ecosystem. This chart should show the most important producers and consumers of each tidal zone.

Activity 3

1. Take a field trip to the beach. Repeat Activity 2 to compare the characteristics of marsh and beach. You may either repeat Activity 1 on the beach or use the field trip outlined in the "Marine Biological Field Techniques" study guide prepared by the OSCSP staff.

Reference

1. Dietrich, G., General Oceanography. New York. Wiley, [illegible]

2. Engel, L., The Sea. New York: Time-Life, 1969

3. Hardy, A. C., The Open Sea. Boston: Houghton Mifflin, 1965

4. Weyl, P. K., Oceanography: An Introduction to the Marine Environment. New York: Wiley, 1970